Unit 1: Atomic Structure and Electron Configuration

Molar Mass

Avogadro’s number: $6.02 \times 10^{23}$, which indicates the particles in a mole of any substance.

Molar Mass: used to refer to the mass of all the molecules in any substance in moles.

Mole: a unit that which measures quantity; 1 mole is equivalent to $6.02 \times 10^{23}$

Percent Composition: Percent by mass of each element in the compound

- 1 mole of *any element* = $6.02 \times 10^{23}$ atoms
- 1 mole = element’s average atomic mass in grams from the periodic table
  - Ex. 1 mol of potassium = $6.02 \times 10^{23}$ atoms or 39.1 grams K
- 1 mole of any *molecular compound* = $6.02 \times 10^{23}$ moles
- 1 mole of any *ionic compound* = $6.02 \times 10^{23}$ (formula units)
  - GFM: Gram formula mass; the mass of one ionic compound
  - Ex. 1 mol of NaCl = 58.5 grams NaCl
- 1 mole of any *gas* = 22.4 Liter

When masses of atoms, molecules and formula units are measured in grams they are termed as:

- **GAM**: Gram Atomic Mass
  - Ex. 1 mol of Carbon = 12.01 grams
- **GMM**: Gram Molecular Mass
  - Ex. 1 mol of H$_2$O = $(1.01 \times 2) + (16.00) = 18$ grams
- **GFM**: Gram Formula Mass
  - Ex. 1 mol of NaCl = 58.5 grams of NaCl

Formulas and Calculations
**Molar Mass** = mass (in grams) / moles

- Ex. Calculating the molar mass of a substance if 0.235 moles of the substance has a mass of 45.67 grams.
  - Molar Mass = 45.67 grams / 0.235 moles = 194 g/mol

**Percent Composition**

- **Mass percent** = total molar mass of an element / molar mass of the whole compound *100%

  - Ex. What is the percent composition by mass of Hydrogen in H₂O
    - Molar mass of H₂ = (1.01 * 2) = 2.02 grams
    - Molar mass of H₂O = (1.01 * 2) + (16.00) = 18.02 grams
    - 2.02/18.02 * 100% = 11.2 % percent composition of H₂

**Atomic Structure and Electron Configuration**

**Atomic Number**: The number of protons in an atom. The periodic table is arranged by increasing atomic number.

**Atomic Mass**: The mass of a single atom of an element expressed in atomic mass units (amu).

**Electron**: Negatively charged particle that is outside the nucleus of a model.

**Ion**: Atom that has a positive or negative charge, due to an imbalance in the number of protons and electrons

**Isotope**: An element whose atoms have different numbers of neutrons, but keep the same number of protons.

**Neutron**: A subatomic particle that has no charge and is in the nucleus.

**Nucleus**: The positively charged dense center of the atom

**Proton**: a subatomic particle that has a positive charge and is in the nucleus

**Wavelength**: Distance between corresponding points of two consecutive waves

**Evolution of Atomic theory**

John Dalton (1808)
● Said that elements are made of atoms, and compounds are formed by combining elements in fixed ratios

J.J. Thompson (1898)
● Realized that the beam produced was negative while working with Cathode Rays
● He was able to measure the charge:mass ratio but not individual quantities
● Made the plum pudding model which shows that negatively charged electrons are stuck on a positive cloud

Robert Millikan (1909)
● “Oil Drop Experiment”: He injected drops of charged drops of oil into an electric field and further explained J.J. Thompson’s answers
● Determined the electron’s charge to be $1.6 \times 10^{-19}$ C.

Ernest Rutherford (1911)
● “Gold Foil Experiment”: He fired a beam of alpha particles at gold foil
  ○ He expected the alpha particles all to go through and most of them did but a few bounced back
  ○ He concluded from the experiment that a small, dense, positive nucleus is in the center of the atom and the electrons must move around it at a large radius

Max Planck
● Said that light could only be emitted in certain energies, which was introduced as quantized energy
● Delta $E = n\hbar v$ or $E = h\nu$
  ○ $E =$ energy of photon (light wave)
  ○ $\nu =$ frequency (Hz)
  ○ $\hbar =$ Planck’s constant: $6.626 \times 10^{-34}$ J/Hz
  ○ $n =$ a whole number

Albert Einstein (1905)
● Said that energy and mass (matter) are interchangeable; they are different forms of the same thing
● Theory of relativity: $E = mc^2$
  ○ $E =$ Energy
  ○ $M =$ mass
○ C = speed of light

Louis de Broglie (1923)
- He stated that particles behave like waves
- Lambda = h/mv
  - Lambda = wavelength
  - H = planck’s constant in J/Hz
  - M = mass of the particle
  - V = velocity

Neils Bohr (1913)
- Said that the emission spectrum of hydrogen made only a few bright lines, not a full spectrum.
- He stated based on his observations that electrons jumping around energy levels create those lines.
- Electrons move around the nucleus in a certain circular orbit
  - Energy available to the electron: \( E = -(2.178 \times 10^{-18} J) \left( z^2/n^2 \right) \)
    - Z = atomic number
    - N = energy level (orbit radius #)
    - Negative sign = the lower the n (the closer to the nucleus) the more negative E is
- Disadvantage: Bohr’s model doesn’t work for atoms other than hydrogen and electrons don’t actually move in an circular orbit

Isotopes
- Atoms of the same element with different mass numbers (due to different number of neutrons)

Formation of ions
- When an atom gains or loses electrons, an ion is formed.
- Electron is gained = negative ion
- Electron is lost = positive ion

**Wavelength**

**Frequency** = # of waves that pass a certain amount of time
**Amplitude** = maximum amount of displacement of a particle on the medium from its rest position

**Speed of light** = \( C = 3.0 \times 10^8 \text{ m/sec} \)

**Wavelength** denoted by lambda
- **Longest wavelength** = long wave radio = least energy (red)
- **Shortest wavelength** = Gamma rays = most energy (violet)

Important relationships
- The longer the wavelength, the lower the frequency (inverse relation)
- The higher the frequency, the higher the energy (direct relation)
- The higher the wavelength, the lower the energy (inverse relation)
- The Electromagnetic Spectrum showcases the different ranges of electromagnetic radiation.

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**Electron Configuration/Orbitals**

<table>
<thead>
<tr>
<th>Energy sublevel and what it looks like</th>
<th>Orbitals</th>
<th># of Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>S (Sphere)</td>
<td>1 (0)</td>
<td>2</td>
</tr>
<tr>
<td>Type of orbital</td>
<td>What it’s used for</td>
<td>More information</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>P (Propeller)</td>
<td>3 (-1,0,1)</td>
<td>6</td>
</tr>
<tr>
<td>D (Double Dumb bell)</td>
<td>5 (-2,-1,0,+1,+2)</td>
<td>10</td>
</tr>
<tr>
<td>F (Frenzy)</td>
<td>7 (-3,-2,-1,0,1,2,3)</td>
<td>14</td>
</tr>
</tbody>
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| N              | ● Principle energy used  
                ● As n increases, energy increases the distance from the nucleus | Specifies the energy of an electron and the size of the orbital  
All orbitals that have the same value of n are said to be in the same shell (level). |
| L              | Energy sublevel    | (0,1,2,3) (s,p,d,f) |
| M_s            | spin               | ● Positive, up arrow ½  
● Negative, down arrow 1/2 |
<table>
<thead>
<tr>
<th>M</th>
<th>Orbital (direction in space)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>● 0,0</td>
</tr>
<tr>
<td></td>
<td>● -1,0,1</td>
</tr>
<tr>
<td></td>
<td>● -2,-1,0,1,2</td>
</tr>
<tr>
<td></td>
<td>● -3,-2,-2,0,1,2,3</td>
</tr>
</tbody>
</table>

Websites that I referenced:

- [https://courses.lumenlearning.com/boundless-chemistry/chapter/molar-mass/](https://courses.lumenlearning.com/boundless-chemistry/chapter/molar-mass/)
- [https://www.chem.fsu.edu/chemlab/chm1045/e_config.html](https://www.chem.fsu.edu/chemlab/chm1045/e_config.html)

Picture: